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Abstract

After a brief review of AMS02 potential for dark matter indirect search, a new code for signal estimate based on micrOMEGAs is presented. It computes gamma ray fluxes from neutralino annihilations as well as the charged cosmic rays and neutrino sources in a general supersymmetric model. This work aims to propose an alternative to the DarkSusy code by providing inclusive Susy signal for dark matter indirect search.

1 AMS02 potential for dark matter search

AMS02 is a high energy particle physics spectrometer to be installed on the ISS for 3 years of data taking. The detector allows to measure cosmic and γ ray fluxes in the 1 GeV to a few TeV range, including particle identification, charge reconstruction, isotopes separation. It consists of different specific sub-detectors, with redundant measurements: a silicon Tracker surrounded by a superconducting magnet, a Time-Of-Flight detector, a Transition Radiation Detector, a Ring Imaging CHerenkov counter and an Electromagnetic CALorimeter [1]. Dark Matter annihilation products could lead to excesses in cosmic rays spectra. Such a signal could be seen in the antimatter to matter ratio for charged cosmic rays (positrons, antiprotons or antideuteron), for which AMS observation capabilities are very high. The positron signal is of particular interest and AMS will precisely measure e^+ with a background rejection of order 10^6, an acceptance of $0.04\,m^2.sr$ and an energy resolution of 3% [2]. For the γ signal, dark matter is expected to produce an enhancement of diffuse emission from the halo and possibly point-like sources where its density is high. Another possibility is to observe a GeV line emission, which would give a compelling evidence for the presence of dark matter since no known astrophysical object could be able to produce it. AMS02 has high performance in γ rays detection with two detection modes depending on whether the photon converts into a e^+e^- pair in the upper detector or not. The Tracker is used in the first case and the Ecal in the other, giving two complementary ways to do γ ray astronomy , with high acceptance (of order $0.06\ m^2.sr$ and $0.09\ m^2.sr$ respectively) and good energy resolution (few %) [3]. The angular resolution is 1^o for the Ecal and 0.05^o in the case of the Tracker for a large sky coverage [3].

2 Supersymmetric dark matter

2.1 Supersymmetry and Cosmology : the micrOMEGAs code

Supersymmetry (Susy) is a very promising extention of the particle physics Standard Model, solving some of its limitations and giving a unified description of particles and interactions. Some Susy models also predict the existence of relic particles from Big-Bang: those are *stable, neutral, massive, weakly interacting and non baryonic.* This possibility is very interesting since cosmology expermiments point out that there must be a large amount of non baryonic dark matter in our Universe (CMB anisotropies, large scale structures, SNIa, see [4]). MicrOMEGAs initial purpose is to accurately compute this relic abundance in a general Susy model [5]. To do so it has to solve a Boltzmann equation, and be able to include about 3000 possible channels. In the following we will work in a particular Susy framework as an illustration, in which Susy breaking is induced by gravity. It is the mSUGRA model, in which all masses and couplings can be derived by fixing 5 parameters at the Planck scale: m_0 (scalar mass), $m_{1/2}$ (fermion mass), A_0 (universal trilinear coupling), $tg(\beta)$ (ratio of the neutral Higgs values in vacuum) and the sign of the Higgs mass parameter μ. In this framework the relic particle is the lighest neutralino $\tilde{\chi}_1^0$ (or χ), a mixing of gauge bosons partners.

2.2 γ ray flux from neutralino annihilations

As an example, we focus here on the γ signal and in particular from Galactic center, whose flux is given by the following expression:

$$\Phi_\gamma^{SUSY}(\Delta\Omega)\,\Delta\Omega = \frac{dN_\gamma}{dSdEdt} = \frac{1}{4\pi}\frac{dN_\gamma}{dE_\gamma}\frac{<\sigma_{ann}v>}{2m_\chi^2}\int_{\Delta\Omega} d\Omega \int_{l.o.s.} \rho_\chi^2(\beta)dl \qquad (1)$$

Two contributions are present in this equation, one purely astrophysical and the other arising from particle physics [6]. The right part corresponds to the density integrals along lines of sight inside $\Delta\Omega$, those depend on the modelisation of the dark halo; eq. **??** is a generic formula allowing to describe various halo types and used in the code.

$$\rho_{CDM}(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1+(r_\odot/a)^\alpha}{1+(r/a)^\alpha}\right]^{\frac{\beta-\alpha}{\alpha}} \qquad (2)$$

In the following, we deal with a Navarro-Frenk-White (NFW) parametrisation, with: $\alpha, \beta, \gamma = 1, 3, 1$, $a = 25\,kpc$ the core radius, $r_\odot = 8\,kpc$ the distance to the Galacic center and $\rho_\odot = 0.3\,GeV.cm^{-3}$ the local dark matter density. In the remaining part of eq. 2.1, the fraction $<\sigma_{ann}v>/m_\chi^2$ contains thermally averaged cross section and the χ mass. dN_γ/dE_γ denotes the number of γ per unit energy for one annihilation.

2.3 micrOMEGAs as an event generator

The final goal of our code is to predict all signals from Susy dark matter annihilations. As the model used here is constrained at the Planck scale, the first step is to compute the evolution of physical parameters such as masses and couplings from the unification scale to the electroweak scale at which cross sections in the halo have to be determined. This part (consisting in solving the renormalisation group equations) is managed by the Suspect code [7]. Then micrOMEGAs computes cross sections and all final states occurences. Those are fermion antifermion pairs, or contain gauge and/or Higgs bosons at tree level. As χ is neutral, it does not couple to photons and there is no tree-level direct γ production. At 1 loop, γ lines are present via the two main processes $\chi\chi \rightarrow \gamma\gamma$ and $\chi\chi \rightarrow \gamma Z^0$ which are implemented in the code [8]. At this point one has to link these final states to detectable particles, and this task is devoted to PYTHIA [9], which computes the partonic hadronisation and the decays of unstable particles. For the γ signal we compute the integral of the density over the field of view. As an example we estimate the signal from the Galactic center in a 1^o opening angle cone and a NFW profile. As an illustration we chose a set of parameters (benchmark G' [10]) for which $m_\chi = 151\ GeV$ and the γ line is particularily visible. For this point, we have $< \sigma_{tot}v >= 7.10^{-28} cm^3 s^{-1}$, with dominant contributions from $b\bar{b}$ (58%) and $\tau^+\tau^-$ (39%). The $\chi\chi \rightarrow \gamma\gamma$ cross section is 1% of the total one with $< \sigma_{\gamma\gamma}v >= 7.10^{-30} cm^3 s^{-1}$. Our code will offer different ways to compute the spectrum: the use as a Monte Carlo generator with a random production event by event, the possibility to generate specific channels before weighting them and the use of tables in order to have a fast estimation of the flux. The second method is used here. Fig. 1 shows the expected spectra with AMS (a few % energy resoltution, on the left) and for a typical atmospheric Cherenkov telescope (a few 10% energy resolution, on the right). Of course this signal has to be added to the background and compared to experimental acceptances. One can notice here the importance of a good energy resolution for such an observation.

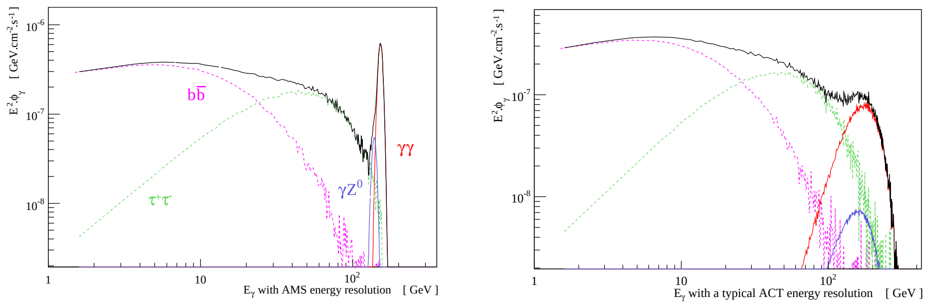

Figure 1: γ flux from Galactic center with different energy resolutions

3 Conclusion and outlook

The example shown here illustrates the potential of such a package. It also points out the importance of the good energy resolution of the AMS02 space mission in the search for dark matter induced γ rays. Nevertheless our code potential is greater than what is shown here: it allows to work in any Susy model and with any halo profile. In the near future, substructures and extragalactic sources studies will be feasible. Some comparisons with the only existing similar tool, DarkSusy [11], are being performed and we are currently working on the implementation of charged cosmic rays channels e^+, $\bar{p}$ and $\bar{D}$, which spectra will precisely be measured by AMS02. To illustrate this,

Fig. 2 shows the e^+ and $\bar{p}$ source spectra; these will be used as input in the propagation equations in order to estimate the flux on the Earth. The work on neutrino channel and direct detection is also under way.

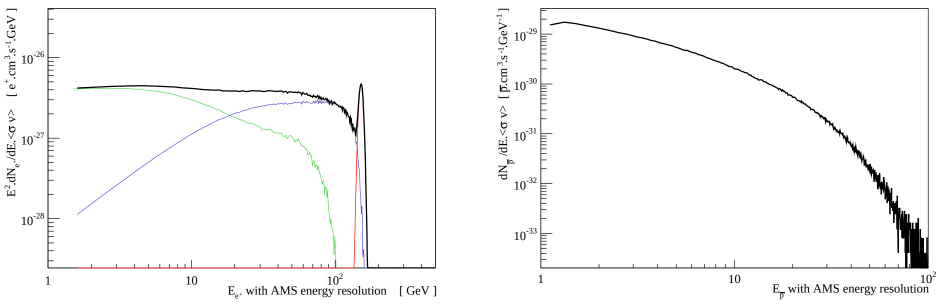

Figure 2: e^+ (left) and $\bar{p}$ (right) source spectra (the color codes are the same as above except for the red line which is used here for the e^+e^- channel)

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